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TECHNICAL MEMORANDUM

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File No. 132473-003

TO: Florence Copper Inc.
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FROM: Haley & Aldrich, Inc.
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SUBJECT: Method for Evaluating Cement Integrity of Steel-Cased PTF Mine Block and Monitoring Wells, Production Test Facility, Florence Copper

Florence Copper Inc. (Florence Copper) has constructed a Production Test Facility (PTF) at the Florence Copper Project in Florence, Arizona (Site) to demonstrate the In-situ Copper Recovery method for the production of copper. The PTF consists of 24 mine block wells, 7 supplemental monitoring wells, and 2 operational monitoring wells within the Permit Area of Review defined in the Underground Injection Control (UIC) permit R9UIC-AZ3-FY11-1 issued by the United States Environmental Protection Agency (USEPA).

The mine block wells consist of 4 types of wells: injection, recovery, observation, and Westbay®. The injection and recovery wells have an outer steel casing that extends from the surface through the overburden that consists of large diameter steel well casing. The overburden casing was installed to the top of the injection zone and the annulus was grouted from the bottom up prior to drilling the lower section of borehole and installing the inner fiberglass reinforced plastic (FRP) well casing. Each of these wells include two grout seals: one between the larger steel casing and the formation, and one between the FRP casing and the steel casing. The supplemental and operational monitoring wells were installed with mild steel casing that is grouted down to the polyvinyl chloride screened interval. These wells are completed in different units, unlike the mine block wells which are all completed in the Bedrock Oxide Unit. The injection, recovery, supplemental monitoring, and operational monitoring wells are the only wells completed with steel casing at the PTF.

In accordance with Part II.C.2 of the UIC permit, Florence Copper ran sonic cement bond logs (CBLs) in each of the steel-cased wells and in the steel overburden casing. This document provides a summary of the results of the CBL evaluations for steel casings at the PTF.

Method for Determining Cement Integrity of Steel-Cased PTF Wells

For the initial evaluation of the casing bond index, a 70 percent average bond (0.7 bond index) across the entire grouted interval was used to evaluate the cement seal integrity. For the steel overburden casings at the injection and recovery wells, which were fluid filled at the time of logging, this data was collected from near surface to the bottom of the grouted interval at a nominal depth of approximately 500 feet for each casing. The same criteria were applied to the CBL logged intervals for the steel cased supplemental and operational steel-cased monitoring wells, which were completed at variable depths. Because the monitoring wells are screened at the bottom they could not be fluid-filled during logging so CBL data is only available below the water table. A table summarizing the average bond index for each of the wells is included as Table 1.

Of the 19 steel casings evaluated, the only ones that did not meet the initial evaluation criteria were the outer steel overburden casings at wells R-02, R-08, and R-09. One shallow well (M-55UBF) did not have enough of a saturated interval to evaluate the bond using the sonic CBL. The wells that did not meet the initial evaluation criteria were subsequently evaluated with additional geophysical tools to evaluate the presence and integrity of the cement seal and to identify conditions that may have affected the bond index values. An additional evaluation of the cement seal between the FRP casing and the steel overburden casing was also conducted following installation and cementing of the FRP casing within the overburden casing.

R-02 EVALUATION

The R-02 steel overburden casing was cemented from the bottom up using a grout shoe welded to the bottom of the steel overburden casing with a stab-in, one-way valve; the volume of grout installed exceeded the calculated volume of the annulus by approximately 7 percent. The results of the bond index analysis indicated an average bond index over the grouted interval at 57 percent. The average bond calculated over the Lower Basin-Fill Unit interval from 283 to 400 feet is 70 percent. However, since the average value over the entire seal interval was below the initial bond index criterion, an ultrasonic acoustic log was also run in the steel overburden casing to examine the presence and integrity of the cement seal.

The ultrasonic Very Large Borehole (VLB) tool is designed to be run in relatively larger casings such as the 14-inch diameter steel overburden casings. This tool is used because the conventional CBL tool is designed to be run in smaller diameter steel casings, and the larger diameter overburden casing may affect the resolution of the conventional CBL tool. The VLB results at R-02 indicate there is a decreased impedance through the zone above the water table, this is likely due to the interaction of the fluid in the cement with the vadose zone and not due to a cement deficiency. The VLB sonic map of the zone below the water table indicates there are no continuous voids or channeling. There is an anomaly on the northwest side of the casing just above the water table at approximately 218 to 226 feet, this discrete zone is limited vertically and horizontally. There is also a discrete anomaly on the northwest side of the casing at approximately 306 to 314 feet. The VLB data below approximately 360 feet is ineffective due to the increased density of the mud inside the casing at the bottom of the casing, the ultrasonic tool is

not compatible with dense drill mud. The VLB logging results do not show evidence of voids or channeling in the cement seal at well R-02. The two anomalies identified are limited in extent and likely reflect lower cement density due to mixing with small amounts of residual drill mud that remained in the borehole during cementing.

The cement seal between the FRP casing and the steel overburden casing at R-02 was also evaluated and found to have no deficiencies based on grout volume and density logging results.

Because no voids were identified and the FRP casing has been installed with a consistent grout seal inside the steel casing, no remedial actions are recommended.

R-08 EVALUATION

The R-08 steel overburden casing was cemented from the bottom up using a grout shoe welded to the bottom of the casing with a stab-in, one-way valve; the volume of grout installed exceeded the calculated volume of the annulus by approximately 21 percent. The higher than expected grout volume is an indication that washouts may have developed after the caliper log was run. The results of the bond index analysis indicated an average bond index over the grouted interval at 42 percent, since this value was below the initial bond index criterion, an ultrasonic acoustic log was also run in the steel overburden casing to examine the presence and integrity of the cement seal.

The VLB log results at R-08 indicate there is a decreased impedance through the zone above the water table, this is likely due to the interaction of the fluid in the cement with the vadose zone rather than a cement deficiency. The VLB sonic map of the zone below the water table indicates there are no continuous voids or channeling. There is an anomaly on the north side of the casing just above the water table at approximately 190 to 205 feet, this discrete zone is limited both vertically and horizontally. There are also discrete anomalies on the northeast side of the casing at approximately 222 to 232 and 244 to 256 feet. The impedance increases gradually through the lower part of the logged zone, likely due to increasing density mud inside the casing, and the log could not be completed past 460 feet. The VLB logging results do not show evidence of voids or channeling in the cement seal at well R-08. The two anomalies identified are limited in extent and likely reflect reduced cement density due to mixing with small amounts of residual drill mud that remained in the borehole during cementing.

The cement seal between the FRP casing and the steel overburden casing at R-08 was also evaluated and found to have no deficiencies based on grout volumes and density logging results.

Because no voids were identified and the FRP casing has been installed with a consistent grout seal inside the steel casing, no remedial actions are recommended.

R-09 EVALUATION

R-09 is the largest diameter well installed at the Site. The steel overburden casing is 16-inches in diameter, whereas all the other injection and recovery wells have 14-inch overburden casing. Consequently, the bond index data has the most potential to be affected by the diameter of the casing

as a result of the CBL operating beyond the limitations of the tool. The R-09 steel overburden casing was cemented by grouting from the bottom up using a grout shoe welded to the bottom of the casing with a stab-in, one-way valve; the volume of grout installed exceeded the calculated volume of the annulus by approximately 2 percent. The results of the bond index analysis indicated an average bond index over the grouted interval at 66 percent. The average bond index across the Lower Basin-Fill Unit from 301 to 378 feet zone is 81 percent. However, since the value across the entire grouted interval for the steel casing was below the initial bond index criterion, an ultrasonic acoustic log was run in the steel overburden casing to examine the presence and integrity of the cement seal.

The VLB log results at R-09 shows decreased impedance through the zone above 40 feet, however, the log was run prior to topping off grout in the annulus which affected the log results in this area. The impedance varies through the Upper Basin-Fill unit with some discrete zones of limited impedance, although no zones decrease to the level of the zone above 40 feet and through the Lower-Basin Fill Unit, the impedance is consistent with variations only noted at casing connections. The VLB logging results do not show evidence of voids or channeling in the cement seal at well R-09. The only cementing anomaly identified was from ground surface down to a depth of 40 feet due to cement settling (and invading the formation) after cement pumping was completed.

The cement seal between the FRP casing and the steel overburden casing at R-09 was also evaluated and found to have no deficiencies based on grout volumes and density logging results.

Because no voids were identified and the FRP casing has been installed with a consistent grout seal inside the steel casing, no remedial actions are recommended.

Closing

We believe this communication is responsive to the requests made by the USEPA and their consultants during the teleconference held on 10 October 2018 regarding evaluation of the cement seal in steel-cased wells. If any additional information is required, please contact me at 602-760-2429.

Enclosure:

Table 1: Summary of Cement Bond Log Index Averages

TABLE

TABLE 1
SUMMARY OF CEMENT BOND LOG INDEX AVERAGES
 FLORENCE COPPER INC.
 FLORENCE, ARIZONA

Well ID	Average Percent Bond Index
I-01	86%
I-02	85%
I-03	80%
I-04	82%
R-01	78%
R-02	57%
R-03	92%
R-04	82%
R-05	73%
R-06	90%
R-07	81%
R-08	42%
R-09	66%
M55-UBF	NC
M56-LBF	79%
M57-O	84%
M58-O	82%
M59-O	86%
M60-O	81%
M61-O	88%

Notes:

% = percent

NC = not calculated due to limited data, saturated interval only ~8 feet